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**INFERENTIAL STATISTICAL ANALYSIS: ISSUES, FOUNDATIONS  
AND SCHOOLS OF THOUGHT**

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INTRODUCTION

Three considerations underlie this bibliography. First, examination of planning studies suggests that inferential statistical techniques often have been, and are being, applied without satisfying test assumptions. Assumptions such as normality, independence, randomness, equal variances and linearity are often overlooked or abused.

While some planners appreciate the significance of assumptions, and thereby compare the opportunities provided by different approaches (e.g., parametric vs. nonparametric), concentration upon benefits of various selected techniques still has resulted in utilization of an unnecessarily narrow range of analytical tools. This leads to the second consideration. When planners attempt to satisfy assumptions and thus carefully compare techniques, all the techniques considered belong to one school of thought of inferential statistics. That is to say, numerous viewpoints are held by statisticians as to the manner in which inferences should be made from a statistic to a parameter. Planners have tended to utilize only one viewpoint, that known as the Neyman/Pearson school of thought. Other schools exist, and deserve consideration.

The third consideration suggests that planners are unaware of the viewpoints of statisticians concerning the normative utility of inferential techniques. Too often statisticians are viewed as theorists who want to play with abstract concepts or else as manipulators who wish to process large data sets with computers.

In other words, statisticians are not usually considered to be aware of "real-world" problems and how their methods may or may not relate to them.

Given the above considerations, or premises, this bibliography has several objectives. One objective is to indicate that many statisticians are concerned with the practicality of their techniques, and that discussion in the statistical literature clearly portrays a variety of viewpoints. Following from this, a second objective is to draw attention to the existence of several alternatives to the Neyman/Pearson school of thought. It is unlikely that these other schools to induction will allow the researcher to resolve all problems associated with statistical analysis. On the other hand, awareness of alternatives may lead to discovering methods that are of utility in specific situations. Furthermore, awareness of alternative viewpoints may lead to a more critical appreciation of techniques presently being utilized. Related to this latter point, a third objective is to emphasize the importance of researchers' satisfying basic test assumptions, regardless of school of thought. Familiarity with alternative viewpoints concerning inferential analysis should result in better appreciation of assumptions.

The objectives noted above determined the organizational format of the bibliography. Three main sections exist. The first presents some statisticians' viewpoints of fundamental issues in statistical analysis. The second provides literature which will introduce the reader to three schools of thought: Neyman/Pearson,

Fisher and Bayes. Section three presents a brief list of introductory texts which could be read to obtain specific details about the various approaches.

To elaborate, the first section is broken into two parts. Part one introduces a variety of views towards statistical analysis as found in the statistics journals. The ideas and concerns expressed are directly relevant to planners, as the statisticians are raising basic questions about the foundations and utility of statistical methods. The references are essentially verbal rather than numeric in format, and should allow readers to become aware of the many dimensions and issues that are of concern to statisticians. These references should also introduce the reader to the material contained in the remainder of the bibliography.

In this context, part two focuses upon one, and what many would argue is the, foundation of inferential statistics--probability. The articles here will indicate that numerous interpretations of probability exist, and that the school of statistical analysis used becomes a function of a prior commitment to an interpretation of probability. In this part of the bibliography, essentially three views of probability are represented. One interpretation, the frequency view, defines probability on the relative long-range outcome of events. It is this interpretation which has led to what is termed varyingly as the classical, orthodox or frequentist school of statistical analysis. The Neyman/Pearson and Fisher approaches adopt this interpretation of probability. The other interpretations are often called the logical

or subjectivist. The former argues that probability is based upon personal belief, and that a "correct" way exists, through application of logic, to operationalize this belief into probability. The latter or subjectivist view perceives probability as derived from personal belief, opinion and experience, and that individuals can articulate their feelings into probabilistic terms. The subjectivist view has led to the Bayesian school of thought.

After considering references in Section A, it is felt that the planner will be aware that different schools of thought exist, and that preoccupation with only one approach is inadequate. Thus, Section B provides material on three schools. Only a few references are provided for the Neyman/Pearson school as this school is the one upon which most planners rely. This school utilizes confidence limits, null hypotheses, significance tests, and other familiar concepts. Thus, the references are intended to provide an appreciation as to where and how the basic ideas evolved. On the other hand, the Fisher approach introduces the notion of fiducial probability and likelihood ratios. Both Neyman/Pearson and Fisher schools of thought are generally categorized as frequentist--based on their interpretation of probability. And yet, sharp differences of opinion exist between proponents of these two approaches.

The third part contains material on the Bayesian approach to inference, an approach criticized by the classical statisticians. It evolved due to questioning of the procedure adopted in the classical schools. The advocates of the Bayesian viewpoint argue that their approach is more relevant to real-world decision

problems than that offered by the supporters of either Neyman/Pearson or Fisher schools. In this part, as well as material covering the basic nature of the Bayesian philosophy, a selected number of references are provided to illustrate the manner in which studies of relevance to planners have applied this technique. Examples range from transportation decisions to water management to weather forecasting. Many more such references exist. Those enclosed suggest the potential and problems inherent in this approach.

The fourth part of Section B attempts to synthesize evaluation of the schools by providing references of two kinds. One type, listed under the heading of comparisons, includes papers which discuss the relative merits of at least two of the three approaches to inferential analysis. The other type, noted under the title of debate, contains references to an ongoing discussion in the American Statistician between classical and subjectivist statisticians. These references, many of which are letters to the editors and relate to articles listed in the first section of the bibliography, should provide documentation as to the ongoing evaluation of statistical procedures by statisticians.

The third and final section, denoted as Selected References contains a very small list of introductory textbooks. These textbooks offer some introduction to inferential statistical analysis in schools other than that of Neyman/Pearson. In this manner, a reader could start to explore, at a basic level, some alternative methods to induction via statistical analysis.

In summary, this bibliography is offered for the reasons indicated at the outset. Planners too often do not satisfy technique assumptions, too often concentrate upon one school of thought of analysis, and too often characterize statisticians as theoreticians or manipulators. In other words, planners too often use techniques without appreciating the theory associated with both techniques and schools of thought. Rational decision making based upon inferential statistical analysis has the pre-requisite that the appropriate school of thought or technique is applied in the appropriate situation. This pre-requisite requires more consideration of alternative approaches to analysis than has presently been shown by planners. Utilization of a bibliography such as this could be a step towards achieving a greater awareness of available alternatives.

A. ISSUES AND CONSIDERATIONS REGARDING INFERENTIAL STATISTICS

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## B. SCHOLARS OF THOUGHT TOWARDS INFERENTIAL STATISTICS

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